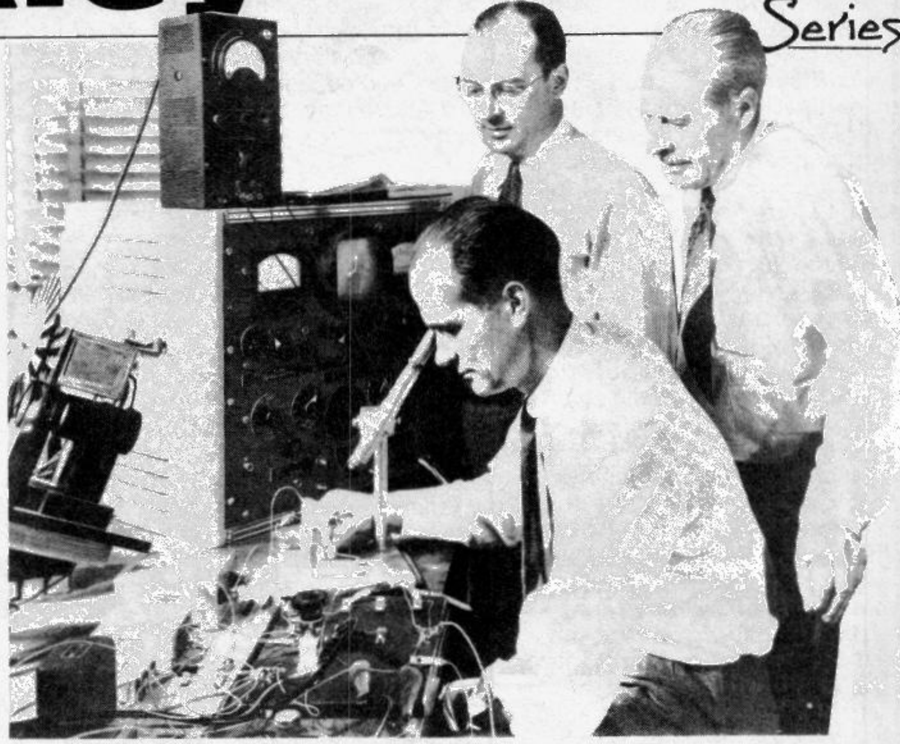
Shockley

Co-inventor of the transfer-resistor.



Seated is Dr. William Shockley, who initiated and directed the Transistor Research program at Bell Laboratories. Standing are Dr. John Bardeen, left, and Dr. Walter H. Brattain. The photo was taken in 1948, when Bell labs announced transistor gains "as high as 20 dB".

SHOCKLEY, Bardeen and Brattain are three names that ring across the post-war years like a summons to a new age. And a new age is just what they started, with their invention of the bipolar transistor in 1948, but there were years of painstaking research before that triumphant announcement in the journal, "Physics Review". Shockley was one of the men who changed the 20th Century more abruptly than anyone else, and this is how it happened . . .

William Bradford Shockley was born in London in 1910 but was educated in the US where his family had moved. He started work, after university, at the Bell Telephone Laboratories in 1936. This, in itself, must have been a remarkable experience because of all the research laboratories around the world, the Bell labs were foremost in telecommunication research, nourished by the profits of the Bell Telephone Corporation. Yes, it's possible to have a telephone system which offers low prices to the user and still make profits for the provider — but don't tell Ma Bell!

Solid States

Throughout the 30s, the Bell labs had pursued a lot of very fundamental physics research which in this country is normally carried out only by universities. Solids, you see, are rather remarkable and when you look at their electrical properties, they seem even more remarkable. Why should one solid element be a metal, bright and lustrous, conducting electricity well, and another solid element be a non-metal, dull and shapeless and an insulator? The nature of gases was dimly understood in the 17th Century, and our understanding greatly increased during the great years of discovery in the 18th and 19th Centuries. The liquid state was being unravelled by theorists in the 19th and 20th Centuries, but the solid state remained very much of a mystery. The main problem was that the atoms of a solid are packed together so tightly that they affect each other much more than happens in gases and liquids. Any theory that took account of the effect that atoms have on each other was likely to become too complicated to solve. The big breakthrough came early in the 20th Century, as a result of work by the great theoretical physicists Planck and (later) Dirac — and the steady follow-up to their work continued in laboratories all around the world. Bell Telephone Laboratories were concentrating on the electrical aspects of solid materials, in the hope that something of importance would emerge. Research is like that; providing that it's genuine scientific research, then there's always some useful outcome, even if it's years later or in some quite unexpected way.

In particular, Bell labs were following up the work on hole conduction in crystals, which had been discovered at the turn of the century, and on the properties of semiconducting materials; it was in these materials that the effects of impurities on conduction (an important clue to what was going on) were most marked.

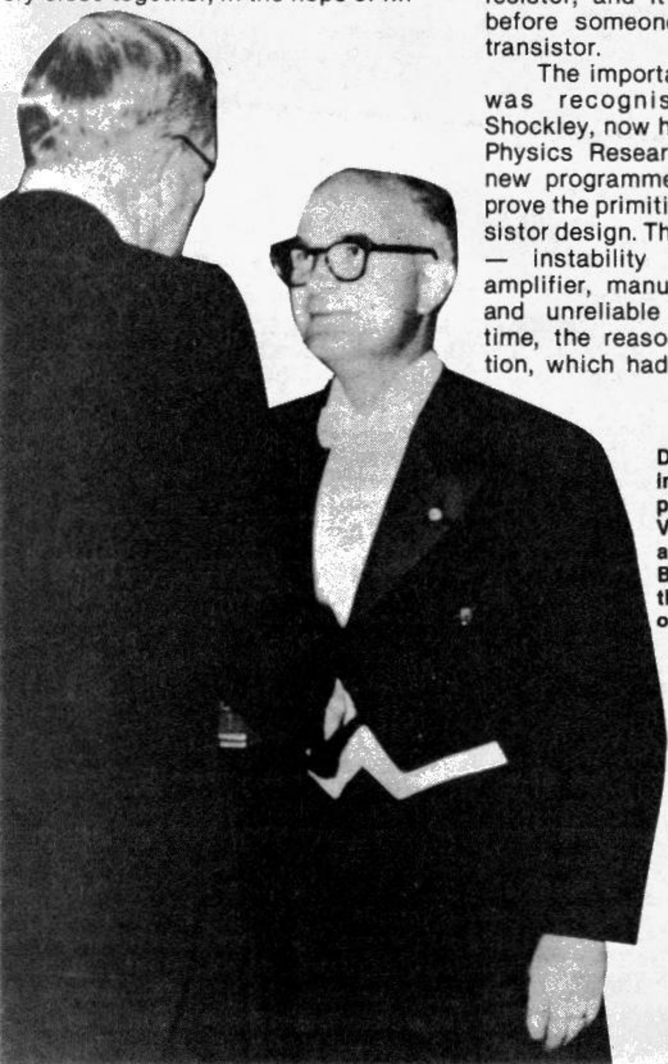
Foundation Stories

The foundations for the invention of the transistor were being laid, then, all through the 30s. There was no great pressure for spectacular results, but there was a steady stream of publications which map out for us how much progress was made. When war broke out, Shockley, along with most of his research team, was seconded to the US Navy to become Director of Research in the Anti-submarine Warfare Operations Group. He worked on all aspects of submarine detection and the effect of depth charges, returning to the Bell Laboratories early in 1945 to resume his research on semiconductors.

By this time, the work was beginning to bear recognisable fruit. The importance of purity was recognised, and the method of re-crystallising germanium by zone refining was developed, leaving the way clear to investigate the doping of the material without the complicating effect of other, stray impurities. It was with such a doped sample that the team, following work which had been done in the 20s with copper sulphide crystals, was able to produce the point-contact transistor.

We should rememuer that the principles which were being followed were quite old. All the way through the 20s, the crystal-and-catswhisker had been used as a sensitive detector (demodulator) for radio waves. The principle was that certain types of crystals, of which metal sulphides were the most useful, conducted; when a fine wire contact, the catswhisker, was allowed to touch the surface of the crystal, a rectifying contact or diode was created. These early detectors used natural crystals and their behaviour was unpredictable and unsatisfactory. You could be listening (using headphones) to a broadcast when it would suddenly vanish until a new sensitive spot was found on the crystal. The problem was that the material of the crystal was never pure and the rectifying action, caused by the material of the catswhisker doping the crystal, would eventually overdope the crystal and stop the action.

There had been reports, too many of them to ignore, of amplifying action obtained by using more than one catswhisker on such crystals, and Shockley's team were hoping that their thoroughly purified materials would allow more consistent results to be observed. They had produced some N-doped germanium crystals and were making contact to them with fine metal wires spaced very close together, in the hope of finding some amplifying effect. The results must have been most gratifying. Those first point-contact transistors were unreliable and had either too little gain for practical use, or so much that they were unstable — but they worked, and worked well enough to allow their characteristics to be studied.

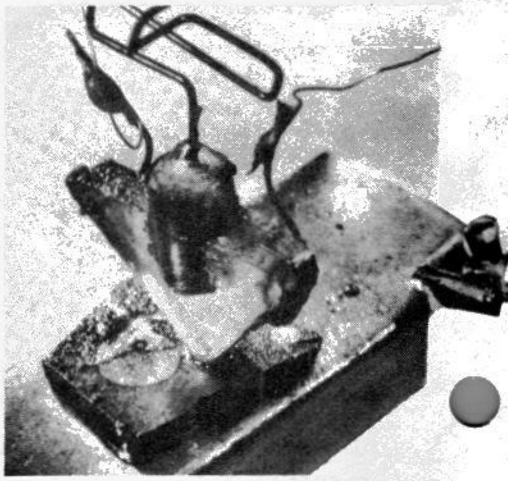


Dr. Shockley in 1956, receiving the Nobel prize in physics from King Gustav VI Adolph of Sweden. The award was shared with Brattain and Bardeen for their work on the invention of the transistor.

Naming Names

The crystal of germanium was dubbed the "base", because it was on this slab of material that the fine wires were located. One wire was called the "emitter", because it appeared to be emitting holes into the base; the other wire was called the "collector", because it appeared to be collecting the holes emitted by the emitter, rather than allowing them to be carried into the base. The circuit was what we would now call a common-base amplifier, and it was this circuit that dominated early transistor technology. The action, by the way, seemed to be that of a resistor which could transfer current to a third connection, so it was called a transfer-resistor, and it was no time at all before someone shortened that to transistor.

The importance of the invention was recognised at once and Shockley, now head of the Transistor Physics Research Dept, initiated a new programme of research to improve the primitive point-contact transistor design. The faults were obvious — instability when used as an amplifier, manufacturing difficulties and unreliable operation. By this time, the reasons for transistor action, which had been worked out in the long years of research, were increasingly better understood and the team was able to turn to better methods of creating the junction between P-type and N-type material, which was so crudely achieved by the point-contact method. It's a matter of history that they succeeded, using the well-documented method of making a sandwich of N-type crystal wafer with contacts of P-type impurity on each side and then heating the sandwich so that the P-type impurity diffused into the germanium, creating regions of P-type germanium on either side of the N-type. This "diffused junction" technique was to dominate transistor construction until the advent of silicon transistors, bringing new techniques that were readily useable only with silicon.



A 1947 point-contact transistor assembled by the inventors. The contact type has been replaced by today's junction transistors.

Shockley was appointed visiting Professor at California Institute of Technology, Pasadena, in 1954, and was further honoured by the Nobel Prize for Physics in 1956. He had, by this time, left Bell Laboratories. From there on, his career turned in a more academic direction as he became, in 1958, a lucturer at Stanford University and, in 1963, the first Poniateff Professor of Engineering Science. In these latter days, he has been more noted for outspoken comment on the topic of genetics and inheritance than on the subjects which made him one of the most illustrious of our Pioneers of Electronics.

ETI